

9/8-9/82

STATUS REPORT: STRUCTURAL PERFORMANCE

✓ Project 2695-21 -- STFI Tester with Modifications

The current objective of this project is to accomplish near term commercial availability of an STFI strip compression tester with automatic measurement of, and correction for sample moisture content. Based on all of our previous work and recent discussions with the Technical Division, we have concluded that the commercial system should be based on the attached set of preliminary specifications. This specification document will be edited and refined to guide design and production of commercial units. We now have a system of this type assembled and operational in the laboratory. It will be available for your inspection and use at the September meeting.

We have opened discussions with L & W, the manufacturer of the tester, through Christer Fellers of STFI. When the laboratory system is complete, (by Sept. 1) and the details specifications are complete, we expect an L & W engineer to come to IPC to discuss design and marketing. Having a working prototype, essentially like commercial units, will be of great help in transferring information.

To assure L & W of a small initial market for the modified tester, we will be soliciting letters of intent to purchase from companies represented in the Technical Division. The abbreviated technical specifications are intended to serve as a base for deciding on such a commitment. Seeing the system in operation in our laboratory would be of great value in such a decision process, hence the push to have it available for the September meeting.

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purposes. These tests have shown the suitability of the STFI tester if enough samples ( $\approx 20$ ) are tested to give a precision comparable to that now achieved with the ring tests (5 samples). Because of the simplicity of the system, 20 STFI tests can be completed more quickly than 5 ring tests. Thus, based on these results, the STFI tester is attractive for possible use in a mill environment for machine-side tests.

For the tester to be practical in a mill context, however, sample moisture measurement and correction must be provided. Again, under FKBG sponsorship, the IPC undertook development of the necessary modifications. Sample conductivity was selected as the basis for moisture measurement, even though it was recognized that the conductivity-moisture correlations are sensitive to mill and grade. From this work a complete moisture measurement and compensation package has evolved, along with industry aggregate correlations of moisture to conductivity and of strength correction factors to moisture content. The specifications set forth below are based on the results of the work described above and discussions with the Technical Division of FKBG whose members will be the ultimate users of the complete tester package. More detailed information on the evolution of the IPC data base and correction system is contained in the series of status reports to the FKBG.

### III. Specifications

#### A. Moisture Measurement System

##### 1. Contacting electrodes

Electrical contact with the sample is to be made with an electrode assembly of the type shown in Figs. 1A & 1B. These electrodes are electrically and mechanically isolated from the normal sample clamps and contact the sample away from the strength measuring zone. This avoids interference with the

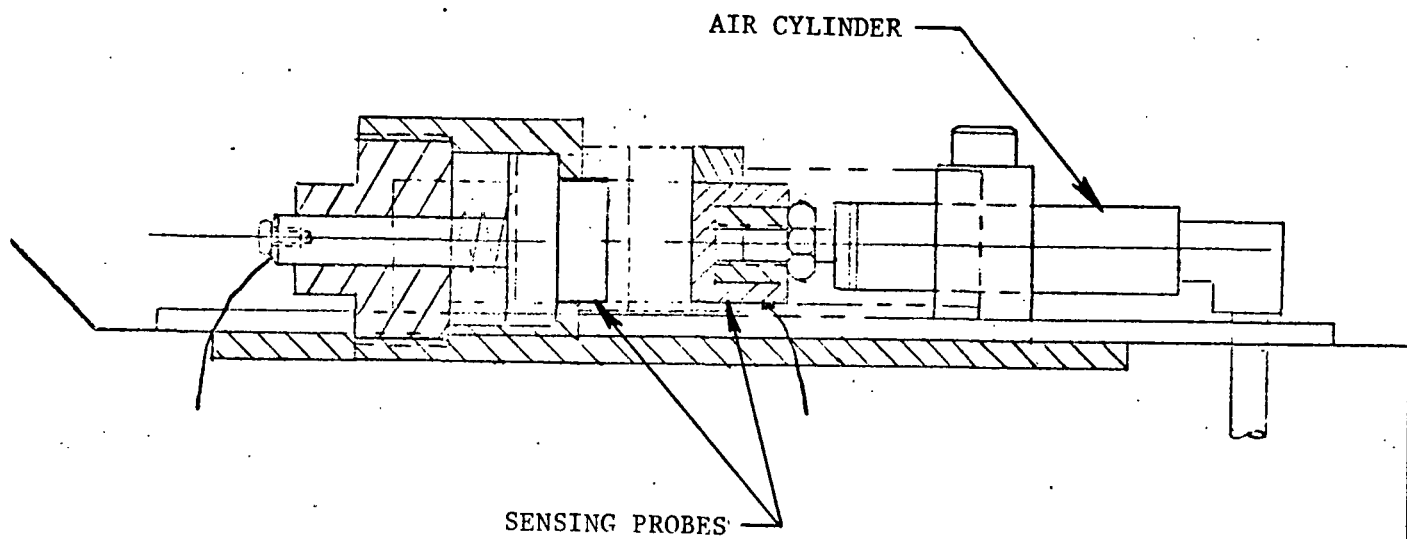
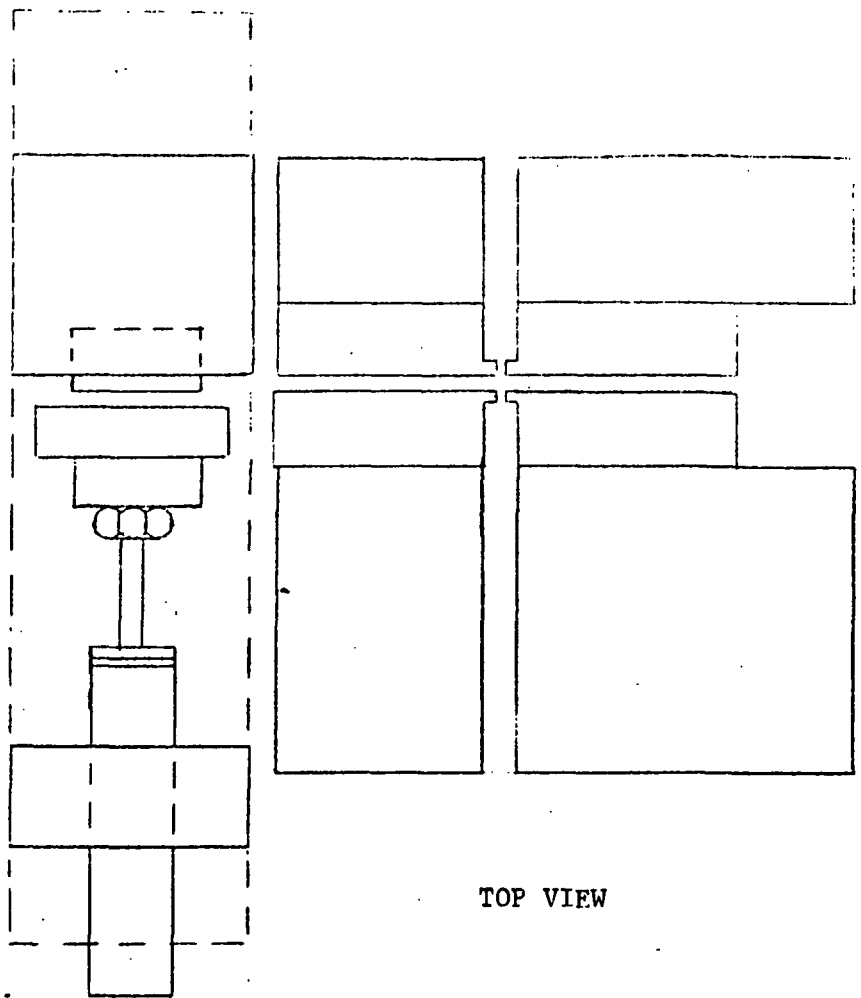
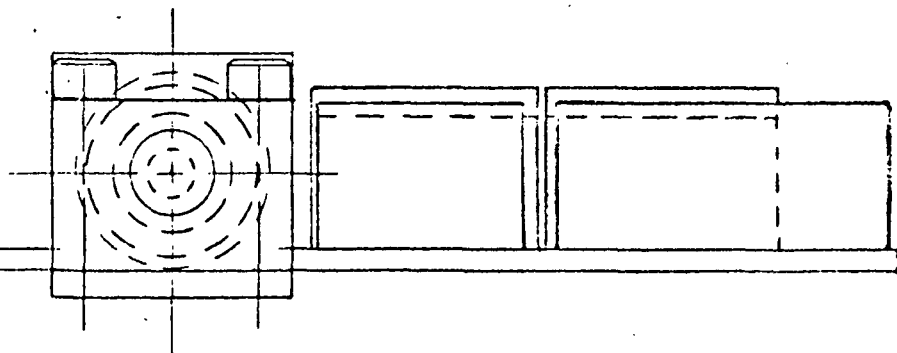


FIGURE 1A. ASSEMBLY DRAWING OF MOISTURE SENSING DEVICE

ALIGN BLOCK FACE  
WITH REAR CLAMP  
JAW FACE



TOP VIEW



FRONT VIEW

FIGURE 1B. LAYOUT OF MOISTURE SENSING DEVICE

strength testing apparatus and permits changing of that apparatus without altering the moisture measurement system or process.

The electrode clamping system is actuated by the existing clamp air supply, thus causing the electrodes to close automatically and simultaneously with the strength slams. Contacting pressure, critical to the precise measurement of conductivity, is controlled by the predetermined and fixed compression of a spring so it is independent of air pressure or sample thickness.

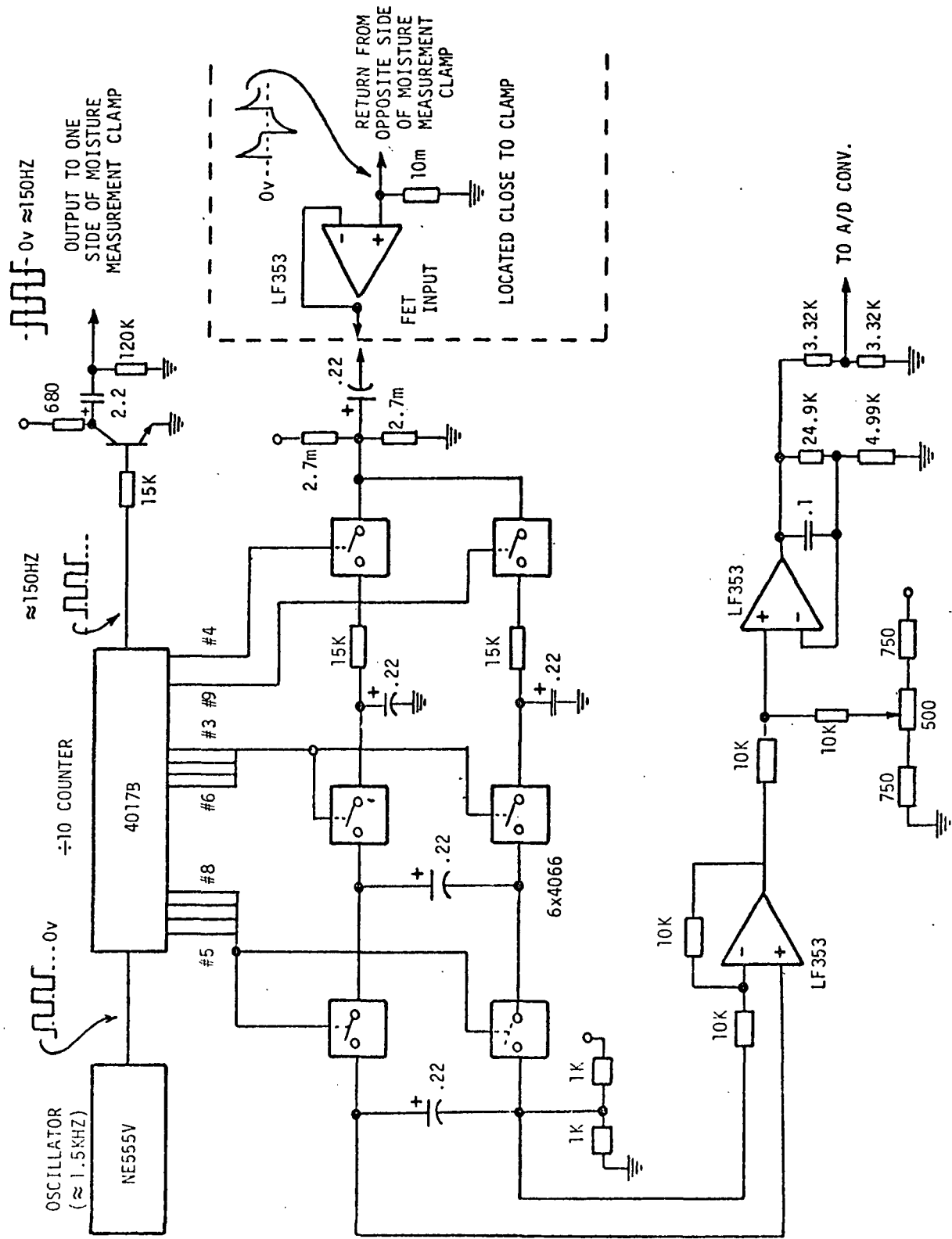
The clamping system mounts on the instrument cover, with air and electrical connections made through the cover.

## 2. Isolation amplifier

Because the sample conductivity for dry samples may be very low (impedance very high), the initial amplifier stage must have a very high input impedance. An operational amplifier with an FET input, operated as a positive follower, is used for this purpose. This stage, shown enclosed in dashed lines in Figure 3, should be located under the instrument cover immediately adjacent to the measuring electrodes.

## 3. Conductivity measurement system

A schematic of the complete conductivity measuring circuit is shown in Figure 3. A 150 HZ square wave, obtained from a 1.5 KHZ square wave oscillator through a divide by 10 counter, is applied across the sample in series with a 10 M $\Omega$  resistor. Hence, the voltage across this resistor is proportional to current through the sample. A large resistance is used to minimize the effect of contact resistance.



Immediately after a square wave transition point there is a current surge because of capacitance effects. This surge decays to a steady state well before the next transition point, as shown in the approximate waveforms in Figure 4. Late in the steady state portion of a half wave the current value is sampled (as shown in Figure 4) and held. For the second half wave the voltage on the sample is reversed and the measurement process repeated. The difference between the two measurements, one for a positive polarity, the other for a negative polarity, gives a good measure of the conductivity of the sample. This measurement process is repeated at the square wave frequency of approximately 150 HZ.

Measurements made by this chopped DC process are equivalent to straight DC conductivity measurements but avoid all the problems associated with DC circuitry. Chopping and comparing opposite half waves avoids the necessity for long term stability in reference voltages and in DC amplifiers. In fact, the system is self-referencing. This approach also avoids the difficulties of single polarity DC measurement of conductivity caused by capacitance and other effects.

Given the proper correlation curve, the conductivity value obtained from this circuit can be converted into a corresponding moisture content value.

#### B. Data Processing System

When modified as specified above, a test on the STFI tester will yield a compressive strength value and a conductivity value, both at the moisture content of the sample. The associated data processing system must, as a minimum, carry out the following steps.

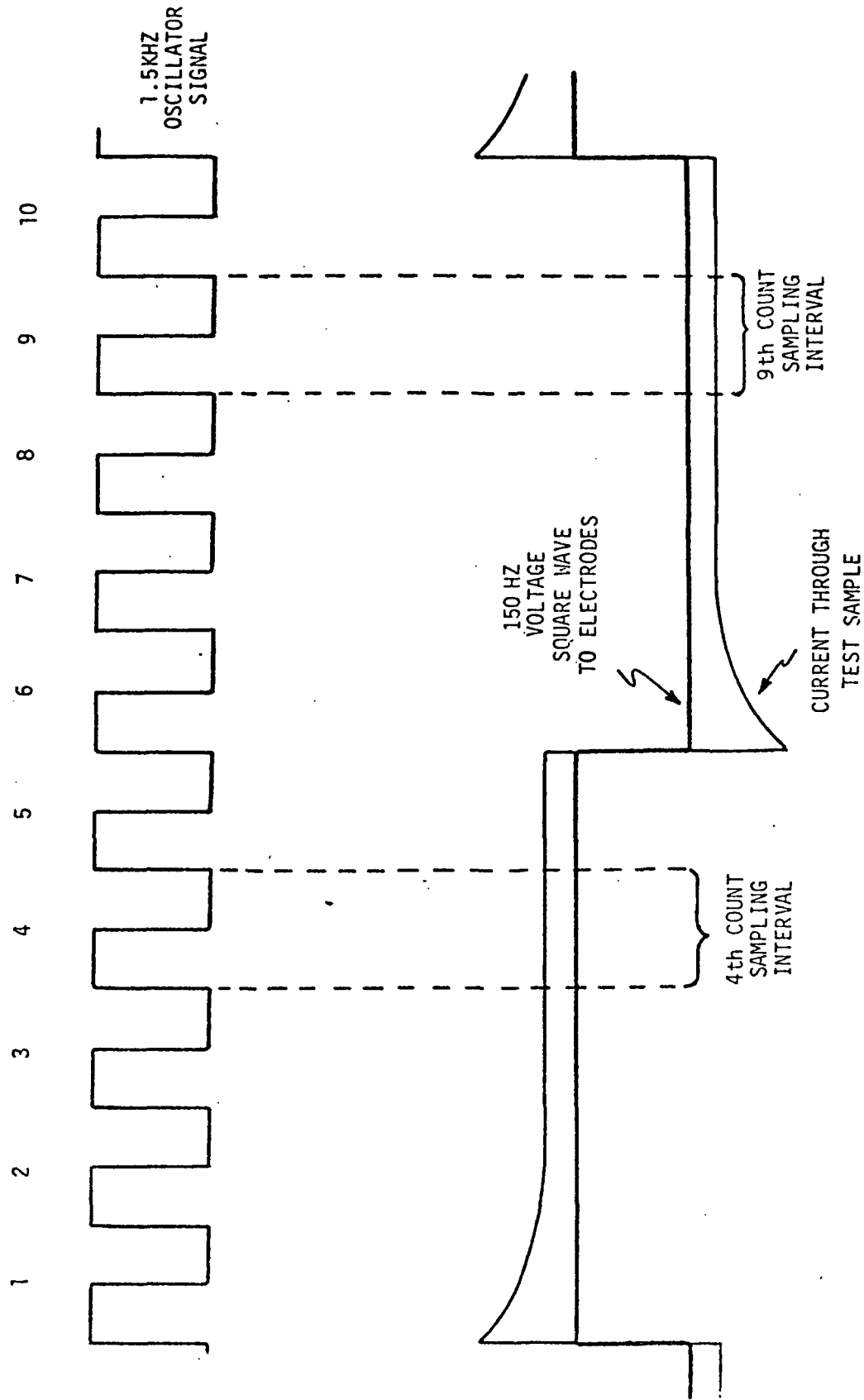


FIGURE 4. APPROXIMATE WAVEFORMS IN CONDUCTIVITY CIRCUIT



- a. Determine the moisture content of the sample from the conductivity value and an appropriate correlation equation or table for the grade tested.
- b. From the moisture value, determine the proper strength correction factor from an equation or table for the grade tested.
- c. Calculate the strength value corrected to standard conditions.
- d. Display or record any or all of these data as desired.

In addition, the data system must provide flexibility in accepting new correlations, in accepting or rejecting data, in the analysis of the data from testing of replicate samples, in displaying or recording sample identification and other important adjunct information, and so on. To provide the needed flexibility a simple microcomputer based system seems most appropriate. To this end, the IPC system is being implemented with an Apple II computer. Many other similar computers would serve equally well. Therefore, the specifications below are in terms of function rather than hardware. The simplified test series flow sheet, shown in Figure 5, will be used as the background for the specifications set. A schematic diagram of the combined STFI tester and Apple II computer is shown in Figure 6.

1. Program storage and start up

An acceptable mass storage device (tape or disk) must be provided for program storage (inclusion of a second unit for data storage may be an attractive option). For purposes of this document a disk system will be assumed. Once the program is stored on a disk, the operator should be able to prepare for a test series by inserting the

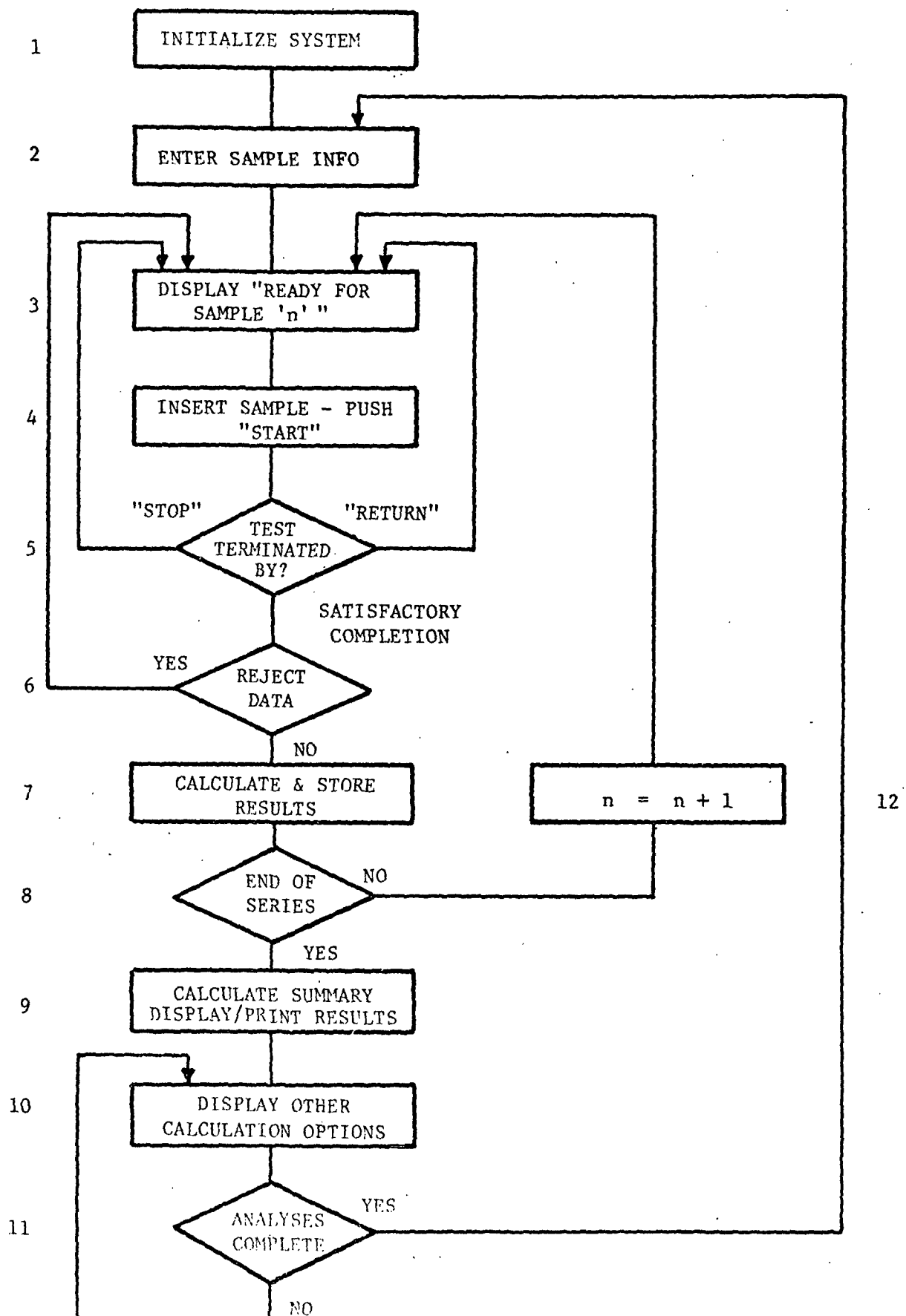


FIGURE 5 SIMPLIFIED TESTING FLOWSHEET

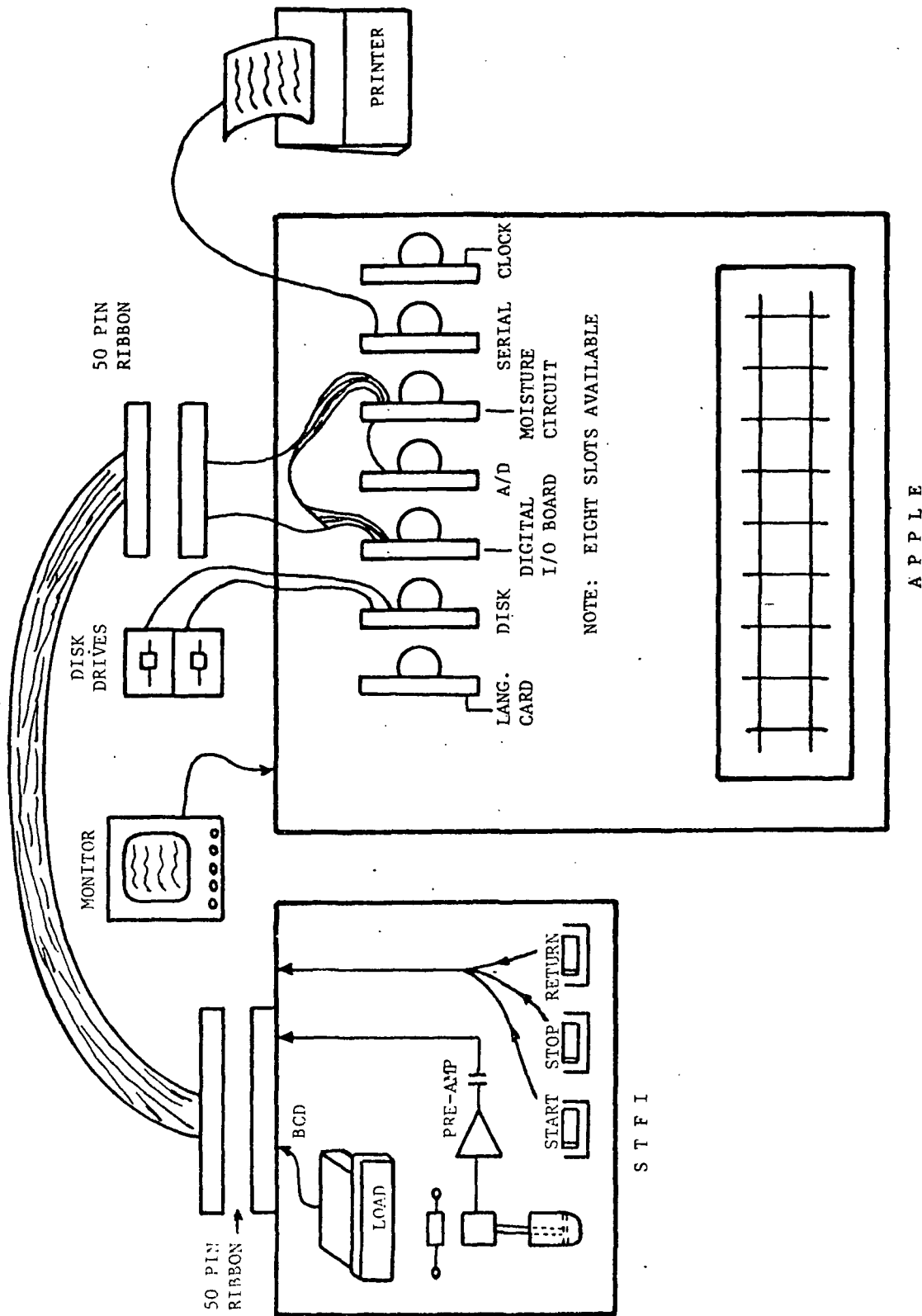


FIGURE 6 STFI w/COMPUTER

disk in the disk drive. This should automatically load the program and initiate running of the program. This is program Step 1 in Figure 5.

2. Entering sample information

The program should prompt the operator to supply the necessary sample identification information and other reference information as selected by the programmer. When this information has been received the computer should display "READY FOR TEST 1" or some equivalent. At this point the computer should be ready to accept strength and moisture data. This completes Steps 2 and 3.

3. Testing samples

In Step 4 the sample is inserted in the STFI tester and the measuring process is initiated by pushing the "START" button on the tester. Once the test has started it may be prematurely terminated by pushing the "STOP" or "RETURN" buttons. These would be used only in the event of an improper test, e.g., a misaligned sample. Termination of a test by either button should reject the corresponding data values and return the computer to Step 3 without incrementing the test number counter. This is Step 5 in the flow sheet. If the test is completed satisfactorily the STFI tester will generate a "test complete" signal to tell the computer to read the strength value and the corresponding conductivity value. The computer should then give the operator a chance to accept or reject these data. Rejection recycles control to Step 3 without incrementing the test number counter.

4. Moisture and correction calculation

If the test values are acceptable by the operator then the moisture and strength correction calculations should be carried out, and the results stored for future use. This is Step 7.

5. Termination of test series

After each successful evaluation of a sample the computer must determine if more samples are to be tested for inclusion in the series. This should be done by comparing the sample number (n) with a desired sample size entered during Step 2 or, in the absence of such an entry, with a default number contained in the program. Manual escape from a test series should be possible at any time. If more tests are required the sample number counter is incremented by 1 and control is returned to Step 3 for testing of the next sample.

6. Summary printout

At the conclusion of a test series the computer should automatically display and print the following:

- a. Sample identification information
- b. Individual sample data for corrected strength and moisture content
- c. Average and standard deviation (or other appropriate measure of precision)

7. Other calculation options

It may be desirable to include a menu of data analysis options from which the operator can order additional analyses. When these are complete and the results printed (displayed), the test series is complete and control reverts to Step 2 for the beginning of the next series.

The above software description is intended to be representative of the minimum set of software capabilities. Because of the system flexibility, the individual user may easily add to or modify the program to suit his or her needs. To avoid unauthorized alterations to a given

software package it must be protectable by using an unalterable compiled version, by a keyboard reset lock out, or some other reliable security system.

#### 8. Correlations for use in Step 4

Initially, the moisture content and strength correction calculation equations or tables will be based on industry aggregate data per grade supplied by the IPC. The software must be so constructed, however, that authorized personnel (see security note above) may easily insert company specific data for these correlations.

#### C. Hardware Implementation

A schematic of a complete system based on the Apple II computer is shown in Figure 6. This diagram is intended to illustrate the desired features of the system and one possible package. Computer systems other than the Apple II should be considered on their overall merit in this application.

##### 1. Equipment regarded as mandatory

- a. Mainframe - with keyboard entry and enough memory to give the user flexibility in programming - programmable in a higher level language, such as BASIC
- b. Mass storage device - at least one disk or tape unit for storage of software
- c. Simple strip printer - with column width and character number and selection adequate for printing sample I.D. and data.
- d. Moisture circuit and A/D board - the conductivity circuit should be assembled as a customized circuit board for insertion in a spare slot in mainframe - this circuit should draw power from the mainframe - (both are possible on the Apple II) - the A/D board should be available from the

mainframe vendor and should also be insertable in a mainframe slot.

- e. The mainframe must also contain the necessary equipment for interfacing with the STFI tester and for operation and control of the computer system.

## 2. Operational equipment

- a. Video monitor - small units are inexpensive and, in this application, would be of great value as an intermediate and temporary display - highly recommended.
- b. Second disk drive - for the creation of special software analyses package or the mass storage of mill operating data, a second disk drive is indispensable - should be offered as an option.
- c. Calendar and clock - for some situations, particularly those involving generation of mill operating trends, printing the time and date on each record would be valuable. To this end, a battery protected real time clock module should be offered as an option.

## D. System accuracy and precision

Addition of a moisture measurement and correction package will not alter the basic function of the STFI strip compression tester. Hence, the uncertainty in measured strength values should be no different from that produced by an unmodified instrument. Moisture measurement and correction for it does introduce additional sources of uncertainty, including:

- a. Uncertainty in the measurement of conductivity - this is determined by the design of the conductivity measuring system.

- b. Uncertainty in the calculation of moisture content from conductivity - for correlations derived from industry aggregate data this source of uncertainty will be fairly large - for correlations derived for a specific machine and furnish, the uncertainty will be much lower - thus, for best result, each mill should ultimately develop its own correlations.
- c. Uncertainty in the strength correction factors in relation to moisture content - these, too, will be a function of local conditions, so the best results will be obtained from locally derived correlations as opposed to industry aggregate correlations. Typically the range of moisture and strength corrections for a single machine will be much less than that for the industry aggregate.

Tests of 68 linerboard samples representing grades of 26, 33, 42, 69, and 90#/MSF and 15 samples of 26#/MSF medium, from a variety of mills, were carried out by the IPC using a simple conductivity measuring system. Details of the test procedures are contained in the reference reports. Based on this simple system and limited data set, strength values for samples tested at various relative humidities were successfully corrected to obtain the strength value corresponding to 50% RH. The error in these corrected data averaged 4.5% with a standard deviation of about 3% over all grades tested. Based on these data the complete measurement package is expected to give  $2\sigma$  precision errors of no more than 6% over the moisture range from 3 to 12%.